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T.CHNICAL AND INVESTIGATIVE SUPPORT FOR HIGH
DENSITY DIGITAL SATELLITE RECORDING SYSTEMS

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Prepared for:

Mr. Jack Hayes, Code 728
NASA/Goddard Space Flight Center
Greenbelt Road
Greenbelt, Maryland 20771

Prepared by:

R. A. Schultz
Associate Engineer
IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616

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FOREWORD

This progress report covers the 16th through 18th monthly periods on IITRI Project K06003 (formerly E06514) entitled, "Technical and Investigative Support for High Density Digital Satellite Recording Systems." The work reported herein was conducted for NASA/Goddard Space Flight Center under Contract No. NAS5-26493 during the period November, 1982 through January, 1983. This report contains results from the surface defect analysis of an Ampex 721 sample along with miscellaneous results of ongoing tape characterization and evaluation tests. Robert A. Schultz conducted the technical investigations with assistance from Frank Jaworski, and Brian Filar.

Data for this report are recorded in IITRI Logbooks C26765 and C27068.

Prepared by

Robert A. Schultz

Robert A. Schultz
Associate Engineer

APPROVED:

H. G. Tobin

Henry G. Tobin, Manager
Instrumentation & Controls
Engineering Research Division

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 Introduction

This report describes recent results of dropout measurements and defect analysis conducted on one reel of Ampex 721 which was submitted for evaluation by the manufacturer. The results or status of other tape evaluation activities are also reviewed. Several changes in test interpretations and applications are recommended. Most of these recommendations were stimulated by our latest round of meetings with recorder and tape manufacturers. In some cases, deficiencies in test methods or equipment have become apparent during continued work on this project and other IITRI tape evaluation projects. Techniques and equipment for future tasks such as tape qualification are also recommended and discussed. In-house acquisition or development of some equipment is anticipated as IITRI continues to upgrade its tape evaluation facility to meet the challenges of advanced HDDR technology.

Project effort and expenditures have been kept at a relatively low level during this reporting period. This rate has provided added development time and experience with the IITRI Dropout Measurement System, which is approaching its potential as a computer based dropout analysis tool. Another benefit is the expanded data base on critical parameters that can be achieved from tests on different tape types and lots as they become available. It has become evident that slight differences between tape lots may have a great effect on the operation of a HDDR system, and an expanded data base could be invaluable for tape type selection. Since tape type availability and formulations are subject to change, more consideration and effort has been directed toward identification of critical parameters, development of meaningful repeatable test procedures, and tape procurement strategy, which will lead to efficient tape qualification methods and reliable supplies for future NASA satellite tape recorders.

2.0 Abrasion Resistance

Three abrasion resistance trials on Fuji yielded a mean value of 2400 passes, a standard deviation of 1370 passes, and a minimum of 826 passes, which compare favorably with the best results from Section 2.4 of Progress Reports #8-11. High abrasion resistance is necessary for video tape binder formulations due to the wear induced by narrow projecting heads during single frame reproducing. Other necessary video tape features such as low dropout rates, good high frequency response, low friction, thickness, back coatings,

and, good environmental stability are also desireable for STR applications. In addition, consistent quality and availability may be enhanced by well defined industry standard and high production volumes of video tapes. Therefore, consideration of more commercial video tape types during future evaluations may lead to identification of a superior product for STR applications.

Some wear of the abrasion resistance test fixture has been noted, and continued wear may eventually affect test results. Consideration will be given to the importance of abrasion resistance, the validity of test results, and the serviceability of the abrasion test fixture before attempting repairs or additional tests. The artificial nature of the dummy head (ball) to tape interface imposed by the abrasion resistance test fixture is readily apparant, and the accelerated test conditions achieved by this interface have an unknown affect on wear mechanisms. The test sample area is too small to reliably detect binder to basefilm adhesion anomalies that have been suggested by low "minimum passes" results on some tape types or other failure mechanisms such as thin oxide coatings over base film asperities. Low speed abrasion resistance testing is discussed with frictional properties in Section 2.0. High speed abrasion resistance testing with tape loops is also under consideration to simulate STR conditions and to test samples large enough to include base film asperities, but sequential dropout measurements during tape conditioning may yield more useful and direct information.

3.0 Coefficient of Friction

A single coefficient of friction measurement on Fuji H621 yielded values of $\mu_s = 0.277$ and $\mu_d = 0.227$, which rank moderately high compared to the results in Table 2.7.1 of Progress Reports #8-11. The NASA supplied friction test equipment failed before Ampex 466 or additional Fuji H621 results could be obtained. The cause of the failure has not been determined, and further testing with this equipment is not advised for several reasons. Friction has not been identified as a critical parameter, in part due to low tensions and high speeds employed during tape head interface studies. The tension and speed of the test transport are difficult to set precisely and tend to drift, especially at the combination of low tension to simulate STR operating conditions and low acceleration (low speed setting) to minimize transients and detect stick slip. The poor documentation and nonserviceable design of the

test equipment may make repairs difficult, and it may not be possible to duplicate test conditions if repairs affect drive circuits. Capturing data with the equipment is difficult because there is no provision for triggering an oscilloscope.

Friction properties at the tape to head interface are most crucial at very low tape speeds, with multiple heads and large wrap angles, and/or during direction changes. These features may be absent in an STR. The possibility of tape to head adhesion after long stops or due to environmental effects on the binder or conditioning effects on the tape surface is a more important consideration for tape qualification. Acquisition or construction of simple, stable, and more versatile test equipment is recommended for future evaluation studies or qualification tests. A synchronous motor driven crank could provide sinusoidal velocities and accelerations which are repeatable and easy to calculate. Tension provided by suspending weights on the free end of the tape would be adjustable, repeatable, almost constant, and easy to calculate at any instant given the known weight and acceleration. Equipment based on these tape drive features would be adaptable to an environmental chamber. Multiple bidirectional measurements of stick slip speed and coefficients of friction during conditioning of a tape sample would be possible. The test drive could be stopped during adverse environmental conditions and restarted to detect head to tape adhesion. A tape drive providing a maximum velocity near 4 ips with a 2.5 second period could subject a three inch length of tape to over 30,000 bidirectional passes during a 24 hour period, simulating many conditions that could be associated with oxide binder wear, including the lack of an air foil effect at low speeds and the transient forces caused by direction changes and stick slip. Frictional and low speed wear properties of a sample could be evaluated in less than two days, including 50,000 passes, measurements with a variety of environments, and adhesion tests (high μ_s) after pauses of the drive at each environment.

4.0 Binder Strength

Recent attempts to repeat the binder strength tests described in Section 2.3 of Progress Reports #8-11 led to ambiguous results, even on adjacent samples from the same reel of tape. The test method is not representative of actual conditions of use. Therefore, deletion of that test is recommended.

5.0 Surface SEM and Elemental Analysis

The surface of Fuji H621 was observed and investigated during defect analysis. At very high magnification that resolves individual particles, smoothness, packing and orientation comparable to 3M 5198 were observed. Larger scale surface features are more apparent optically and were described for both tape types in Progress Reports #12-15. A trace of chromium was detected in the Fuji binder which is probably an oxide additive.

IITRI guidelines for tape evaluation express reservations regarding binder formulations containing chlorine. Although this element has been detected at trace levels in all tape types, there are no indications of excessive levels. Chlorine probably results from the vinyl chloride of a copolymer such as VAGH, which is a typical minor component added to the polyurethane of tape binders. Since recent STR failures have not involved head corrosion or tape head adhesion problems associated with high chlorine levels, further investigation of chlorine in candidate tape types is not recommended.

6.0 Abrasivity

Alfesil bar tests on three Fuji H621 lot 079552 samples with the procedure of Section 2.8 in Progress Reports #8-11 yielded a mean wear width of 2.18 mils with a standard deviation of 0.43. The 0.91 normalized value places Fuji H621 in the high abrasivity catagory with 3M 5198 and Ampex 721 as compared to Ampex 466 and Ampex 797 results.

Abrasivity has not been identified as a crucial STR parameter. The use of a single tape at high speeds, low tension, and moderate humidity reduce abrasivity. The high abrasivity category mentioned above is probably satisfactory to prevent degrading deposit buildups on STR heads without inducing undue wear rates. However, since test results are difficult to interpret, the quality assurance applications of the tests should be considered rather than use of the results for tape type evaluation or selection. Abrasive properties are susceptible to slight production variations, and important changes might be detected by comparing bar test results from one sample of each tape lot procured for STR applications.

IITRI will continue to monitor and evaluate abrasivity test methods. The SCAT bar test method employs a more typical head surface contour and

tape conditioning more representative of STR applications. A copy of a "standard" test procedure is enclosed, but development of an STR test method with preconditioning or more passes and a bar material the same as the head material should be considered.

7.0 Lubricant Content

Fuji H621 Lubricant contents of 1.40% and 1.13% for benzene extractions and freon extractions respectively fall within the 1-2% IITRI guidelines and are moderate values compared to the ranges of Section 2.5 in Progress Reports #8-11. An extension of lubricant content test techniques has been developed for lubricant analysis and as initial steps for chemical characterization. A single tape sample is subject to a series of extractions by increasingly polar ultra pure solvents. Then the solvents are evaporated, leaving the lubricants and other solubles for weighing, spectroscopy and/pr chromatography.

The general class of lubricant can generally be identified by infrared spectroscopy. The presence of other solubles may be sensitive to incomplete curing or formulation changes and can lead to the identification of binder components which are not detectable in the cured coating. The extraction of unreacted binder components will suggest mechanisms for deposit generation which can be compared to defect analyses and cleanliness test results for verification of problems and recommendations to tape manufacturers. Implementation of those procedures during task 6 is possible, but the value of the information to project objectives should be reviewed.

8.0 Chemical Characterization

Due to the complex formulations typical of modern tape binders, detailed identification and quantitative analysis of components is not recommeded. Chemical "fingerprint"techniques are under consideration to detect formulation charges, but these methods generally do not provide much useful information. The microprobe methods described in Section 2.6 of Progress Reports #8-11 suffer from poor repeatability and insensitivity to organic components, especially at the functional group and molecular cross linking levels where significant changes in tape properties are likely to arise. Surface infrared spectroscopy has been attempted, but the surface texture of tape causes

difficulty at important wavelengths, and low concentrations of important modifiers cannot be detected. Binder polymers tend to be so chemically resistant that convential hydrolysis methods alter the identity of binder polymers before they can be separated and analyzed by chromatography and spectroscopy.

Pyrolysis/gas chromatography (PGC) is a semiquantative technique which may be sensitive and repeatable enough to provide suitable "chemical fingerprints" of complex binder polymers. Pyrolysis breaks the binder into approximately monomer size fragements through the rapid application of thermal or radiant energy. The fragments separate according to molecular weight and/or polarization as they are carried down the chromatograph column by the carrier gas, and a detector at the outlet of the column senses each fragment, which results in a peak on an output chart for each fragment. Peak sizes are roughly proportional to the amount of each fragment produced.

Different monomer types in two binders will result in different PGC peak positions, while different proportions of monomers and components will affect the size of the resulting peaks relative to each other. Differences in the degree of cross linking may produce different types or proportions of fragments. Even minor binder components are likely to produce observeable peaks.

Identification of PGC peaks is occassionally possible by comparison with reference PGCs prepared from known binder components. Fragments can also be collected for more extensive analytical techniques, but it is very difficult to determine the complete binder composition or the structural relation of binder components to each other, even if the identity and amount of each fragment is known. Even the use of PGC as a "fingerprint" to detect binder changes is recommended with some apprehension because significant levels of difference cannot be well defined when comparing two PGC's. Although instruments are designed to produce precise and controllable pyrolysis conditions, slight variations with time can be expected and may alter the fragments obtained from identical samples. Samples to be compared by PGC should be run consecutively. However, polymers can also change with time, so a PGC should also be obtained for each tape lot at the time of procurement for comparison with PGCs of later lots. With these precautions, changes due to binder aging or pyrolysis conditions (but not both simultaneously) can be

detected, and PGC can provide a sensitive probe for binder composition changes.

Observation of different "chemical fingerprints" for samples obtained from different tape lots will indicate a need for more extensive physical testing prior to qualification of the new tape lot. Since "fingerprint" results in general cannot be precisely interpreted, the changes are not likely to guide in the selection of additional tests. In addition, identical PGC results from two tape samples will not guarantee identical performance, since factors such as surface finish, and oxide and base film properties are not likely to affect PGC results but can affect tape performance.

Even if a compex binder polymer was thoroughly analyzed to the point of identifying the composition and amount of each starting product as well as the polymer structure, the degree of crosslinking, and variations both between and within production lots, polymer science has not reached a point where this information would enable precise prediction of tape properties. Therefore, less emphasis on chemical characterization is recommended for a tape qualification program. A few "fingerprint" tests such as PGC may be considered to supplement physical testing of properties critical to an STR application or known to be marginal or variable within a selected tape type, but more extensive effort should be restricted to analysis of well defined tape problems.

9.0 Magnetic Properties

A coercivity temperature coefficient of -1.7 oersteds/^{o}C was obtained for Fuji H621 over a -18^{o}C to 40^{o}C temperature range which is similar to Ampex 721 over that range. In comparison, 3M 5198 is more stable at -1.2 oersteds/^{o}C while Ampex 466 was relatively unstable at -2.8 oersteds/^{o}C. Measurement of Fuji H621 coercivity at 60^{o}C could not be carried during this report period. Since unstable coefficients as great as -5 oersteds/^{o}C have been measured in commercial products and are considered highly significant over STR operating temperature ranges, this measurement should be required for qualification of high energy tapes.

The low squareness values and related results obtained for Ampex 721 and other high energy tapes has since been verified by Ampex. The difference between the 0.80 value reported by IITRI and the 0.75 value obtained by

Ampex is probably caused by the higher maximum applied field of 5000 oersteds employed by Ampex. Apparently, coercivity is more important to good high frequency performance than orientation when Ampex 797 is compared to high energy tapes.

The differences in measured squareness and the general lack of clearcut correlations between magnetic properties and record/reproduce performance of the high energy tapes demonstrates that magnetic measurements are not sufficiently sensitive to predict differences between high frequency performance of very similar tape types. Magnetic measurements should be continued to detect gross changes between oxide properties, packing, or orientation of different tape lots.

10.0 Tracking and Guidance

Tracking and guidance is an important parameter for narrow track systems which has not yet been investigated. Plans to measure tracking repeatability with environmental variations have been delayed due to the emphasis placed on dropout measurements and environmental limitations of the video inspection equipment formerly employed by IITRI for these measurements. We plan to upgrade our tracking and guidance measurement capability with non-contact fiber optic displacement sensors which have the sensitivity and thermal stability required for this project. Acquisition of the equipment and completion of the measurements is anticipated within six months.

11.0 Dropout Measurements and Defect Analysis

Dropout measurements were continued to assure a supply of screened tape for OEMs and to analyze a recently received lot of Ampex 721. Dropout screening has been accomplished for 3M 973 at the request of RCA. The quantity of that tape type is limited, and extensive testing of other properties has not been scheduled. Table 4.4.1 of Progress Reports #8-11 indicated good dropout performance for 1/4 inch Ampex 466 samples with 18 mil tracks. Virgin, 1-inch Ampex 466 is not available for comparative testing with 7 mil tracks, and current Ampex 721 results suggest a base film problem that could also affect Ampex 466. These tape types should not be eliminated from future consideration because a resolution of the base film problem could vastly improve dropout performance, and Ampex 466 has desirable pro-

perties such as high abrasion resistance.

Defect analysis has led to conclusions concerning the effects of conditioning and cleaning for specific tape types. Mounting of the RCA head for correlation studies of bit error and dropout maps is complete, but additional improvement of the electrical interface will be attempted. In addition, measurement instrumentation for the phase shift induced single bit error tests is ready, but actual measurements on tape have not yet been attempted.

11.1 Dropout Screening

Table 1 is an updated version of Table 4.5.1 in Progress Reports #8-11. Two additional Fuji H621 reels (lines 6 and 7 of Table 1) were screened to provide a total sample length comparable to the 3M 5198 samples, and to provide Lockheed with tape comparable to the two reels (lines 3 and 5 of Table 1) previously supplied to RCA. The results show that the high dropout rate obtained from the first lot 079552 reel of Fuji H621 was not a lot specific phenomenon.

Several tracks on an Ampex 721 evaluation reel were also screened. Error rates were intermediate between Fuji H621 and 3M 5198 results, while dropout rates were equal to 3M 5198 and average dropout length was substantially below the 200 wavelength values characteristic of the other two types. In addition, a high track to track variation was measured, which was matched only by the 3M 5198 sample shown to have a repeating base film asperity defect. These results suggest repeating defects on one or more of the Ampex 721 tracks included in the sample.

11.2 Defect Analysis

Table 2 is an updated version of Table 5.1 in Progress Reports #12-15 which includes results from high resolution mapping of an Ampex 721 sample before and after the dropout screening and a second recording of that sample. A much greater proportion of permanent dropouts was present on the Ampex 721 sample than on the other two tape types.

Table 1: Error Rates from 20 dB Dropouts on 7.3 Mil Wide Tracks of Fuji H621. 3M 5198 and Ampex 721

Tape Type (lot of reel)	Section of Reel Analyzed (feet)	Error Rate (Errors/10^6 wavelengths)														Dropout Rate $\left(\frac{\text{Dropouts}}{\text{100 feet}}\right)$	Average Dropout Length $\left(\frac{\text{Errors}}{\text{Dropout}}\right)$
		Location of Track Center (±5 mils from edge)													Average for all Tracks		
		315	336	357	377	398	419	440	461	482	502	523	544	565			
Fuji H621* (079552)	300 to 2900	9.1	7.3	3.7	7.8	9.7	6.2	6.8	4.1	3.5	7.1	4.6	4.2	3.7	6.0	0.52	228
Fuji H621 (079903)	300 to 2900	1.2	2.8	4.3	4.7	3.4	2.1	2.0	2.2	3.3	2.3	3.3	3.7	2.7	2.9	0.33	177
Fuji H621 (079903)	300 to 2900	1.4	1.7	2.6	3.5	4.0	1.4	0.6	1.1	0.9	2.3	2.9	2.7	2.4	2.1	0.23	186
Fuji H621*** (079903)	200 to 2900	3.9	3.3	3.9	4.2	4.2	2.5	2.4	4.9	2.9	7.9	15.3	7.2	3.2	5.1	0.35	291
Fuji H621 (079903)	200 to 2900	3.3	2.7	2.8	1.6	2.2	2.3	1.2	2.9	1.8	0.9	1.7	1.8	4.1	2.2	0.22	205
Fuji H621 (079552)	200 to 2900	2.6	2.6	2.8	2.6	2.7	1.5	3.0	4.2	0.9	2.7	0.8	3.0	2.4	2.5	0.25	193
Fuji H621 (079552)	200 to 2900	2.0	4.3	2.5	2.6	4.2	2.7	1.0	1.6	1.7	1.7	1.5	1.9	1.4	2.2	0.20	223
3M 5198 (43056 17 010 9)	800 to 8400	13.6	15.9	12.8	11.6	12.7	10.9	13.7	12.3	12.0	10.9	10.1	15.6	10.4	12.5	1.46	173
3M 5198 (43056 17 010 16)	1500 to 8900	25.6	22.7	35.3	25.8	26.9	20.3	26.6	22.2	18.5	30.3	17.3	20.2	23.3	24.2	2.42	200
3M 5198 (43056 17 010 24)	600 to 8400	8.9	12.3	11.8	12.5	10.1	10.3	10.7	10.8	12.4	80.4	18.7	19.1	14.5	12.5	1.24**	186**
Ampex 721 (MIL 5948 59GK11)	1800 to 9200	6.8	2.8	19.6	11.3	2.4	7.8	7.1	8.4	12.0	--	--	--	--	8.7	1.45	136

*Transport malfunction may have increased errors and dropouts by 3% for tracks 440 through 565

**Does not include data from track 502

***High error rates on tracks 502, 523, and 534 include errors from a single large dropout which was not redetected after degaussing and re-recording sample. Average for all tracks without this dropout were 3.8 errors/10^6 wavelengths, 222 errors/dropout, and 0.34 dropouts/100 feet.

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Table 2

Dropout Measurements Following the Virgin Recording and a Second Recording of 3M 5198, Fuji H621, and Ampex 721

Sample	SAMPLE SIZE			DROPOUT COUNTS				TOTAL LENGTH OF DROPOUTS (mils)			
								ALL DROPOUTS		PERMANENT DROPOUTS	
	Length (feet)	Tracks	Area ($inch^2$)	Virgin Recording	Second Recording	Permanent	Identified & Analyzed	Virgin Recording	Second Recording	Virgin Recording	Second Recording
3M 5198 - A	200	8	95	11	7	5	2	250	42	77	24
3M 5198 - B	250	8	119	17	10	7	2	214	90	36	34
3M 5198 - C	300	20	387	54	28	20	10	663	135	352	94
3M 5198 - D	300	11	219	25	11	5	5	250	88	94	62
3M 5198 Averages Per Square Foot	-	-	-	19	10	6	-	242	62	101	38
Fuji H621 - A	300	20	387	8	7	1	0	257	163	4	7
Fuji H621 - B	300	14	275	3	5	0	0	93	22	0	0
Fuji H621 Averages Per Square Foot	-	-	-	2	3	<1	-	76	40	1	2
Ampex 721-A	290	20	374	63	58	48	3*	699	525	583	461
Ampex 721 Average Per Square Foot	-	-	-	24	22	18	-	269	202	224	177

*Includes representatives of two repeating defects that account for 90% of permanent dropouts.

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11.2.1 Defect A721-1-A

At least three-quarters of the permanent defects occurred on six adjacent tracks along one side of the twenty track map, suggesting a repeating defect with a "wandering" transverse location similar to the base film asperity identified on 3M 5198, which was not included on any of the Table 2 samples. Practically every five foot sample on the affected non-edge tracks had dropouts on two adjacent tracks, suggesting an effective width of 11 to 15 mils. Generally bi-lobe signal envelopes suggest projecting oxide material, allowing average dropout lengths shorter than the indicated width and accounting for the atypically short average dropout length on Table 1.

Several copies of the repeating defect isolated from the Ampex 721 sample exhibited a minimum distance of 46 inches between copies. The interference micrographs of Figures 1a and 1b were taken before and after oxide removal respectively at one copy of the defect with the interference planes oriented parallel to the tape surface. A base film asperity is clearly indicated, and a thin oxide coating over most or all of the asperity is suggested by the absence of longitudinal scratch marks on the micrographs and the complex shape before removal of the oxide. The micrographs suggest a projection height equivalent to the 3M 5198 base film asperity but a narrower width at that height, correlating well with the 2-6 mil difference in effective widths reported for the two base film asperities.

Visual scanning and interference microscopy verified the presence of a second repeating base film asperity on this 1 inch wide Ampex 721 reel. Visual scanning suggested four more repeating base film asperities which could not be verified by the "before and after oxide removal" technique due to the textured base film surface visible around the perimeter of Figure 1b, which can obscure moderately spaced interference bands on irregular shapes.

11.2.2 Defect A721-2-A

At least two additional permanent dropouts on the Ampex 721 sample were caused by copies of another repeating defect which only affected a single track. This distribution and width suggests a low profile projection (or a narrow depression) formed during a manufacturing step, which exhibits nominal transverse shifting compared with the wandering location

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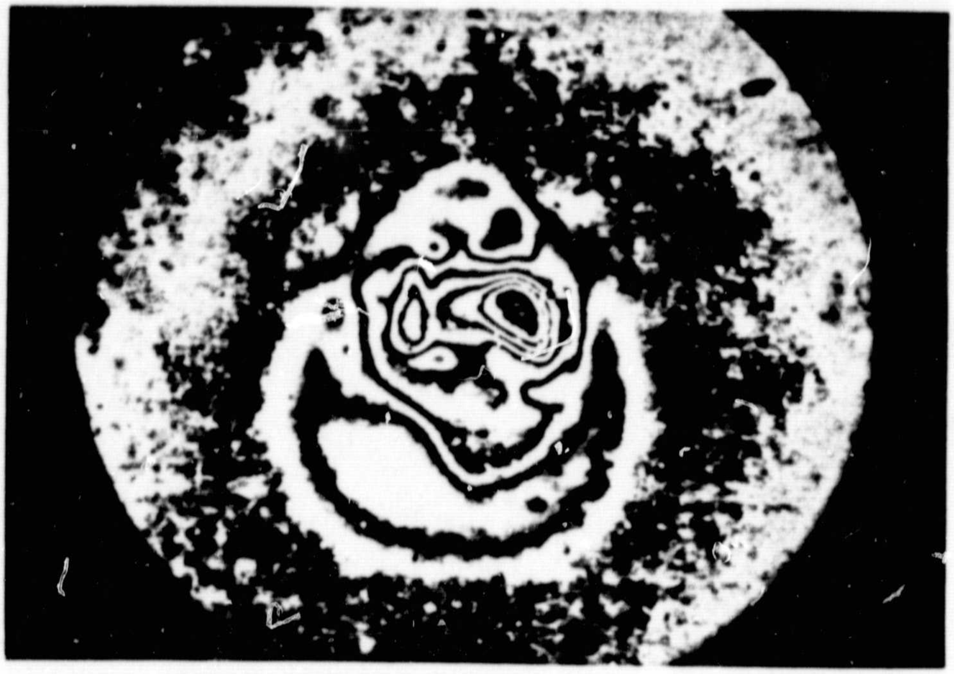
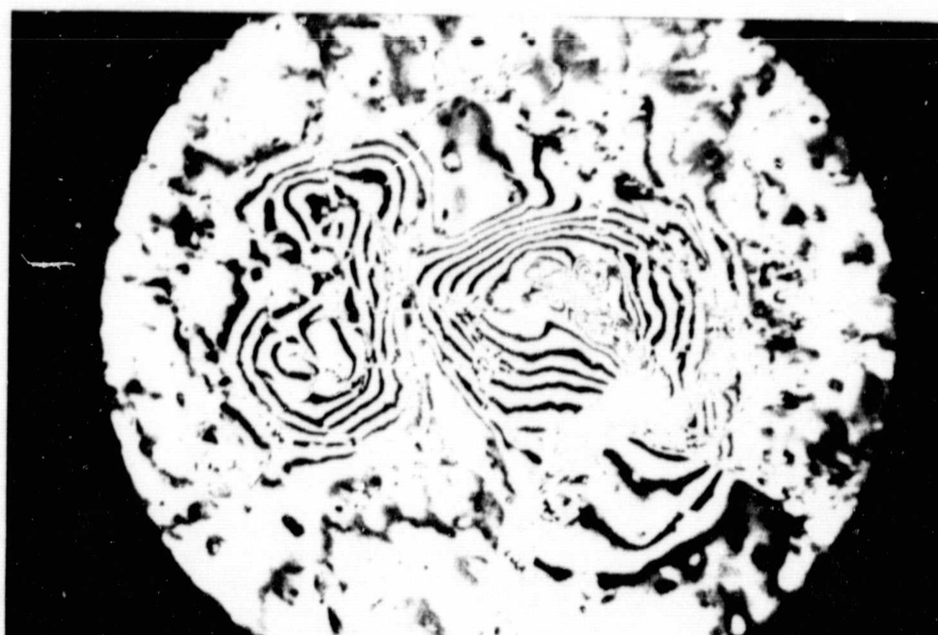


~40 μ in high
implies a ~140
opacity in base
film.

a.



b.

Figure 1: Defect A721-1-A (a) before and (b) after oxide removal. Magnifications are (a) 140 x and (b) 340 x.

Base film defect
repeats — most
Cause d.o.

of the base film asperity. A 46 inch separation distance was also observed between copies of this defect, but distances between dropouts were irregular and much greater due to the borderline size of the defect and/or its position relative to track centers.

Figures 2a and 2b are micrographs showing the size and shape of a defect copy which was probably responsible for a dropout. The base film surface appeared normal after removal of the oxide, indicating a calendaring defect with streaks suggesting smearing of the defect material prior to curing of the oxide. The rim along the extreme left edge of Figure 2b projects 30 microinches above the tape surface. A shift of about 4 bands (40 microinches) is visible toward the right edge of the upper interior streak, but the width of that projection may cause less head to tape separation than the rim.

11.2.3 Defect A721-3-A

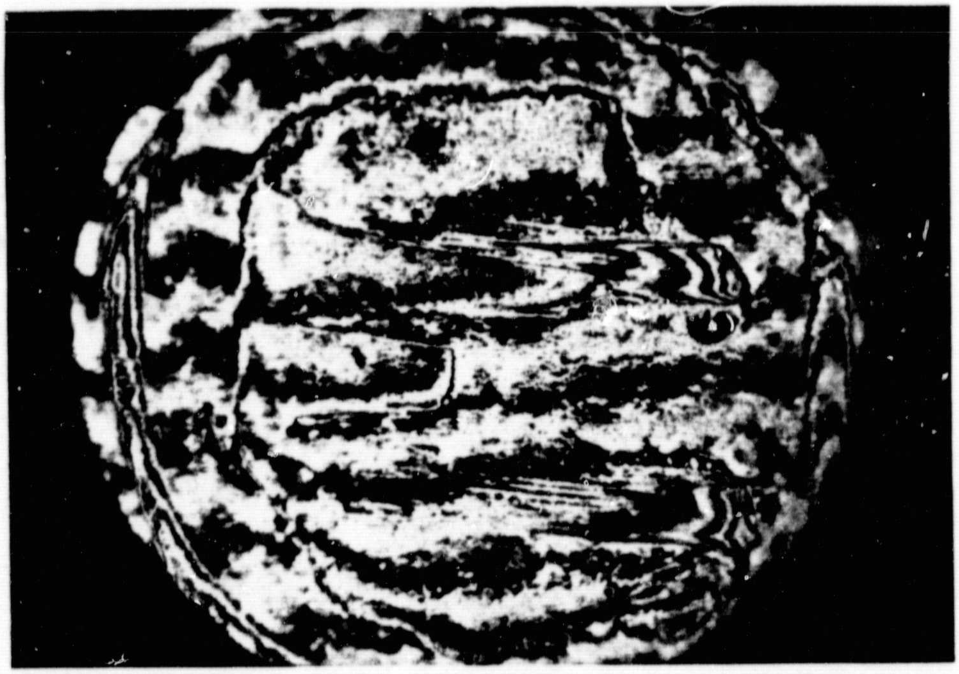
Figure 3 is a white light interference micrograph of one smeared defect located on the Ampex 721 sample. The 3.7 band shift on the smooth right portion of the defect indicates a 44 microinch projection. The rough surface on the left portion of the defect could obscure a greater projection. The optical appearance of this defect was similar to the common deposit defects of 3M 5198, and additional analytical characterization was not deemed necessary since this defect type is not a predominant cause of permanent dropouts on the Ampex 721 sample.

11.3 Conclusions

Predominant defect types on the 3M 5198 samples and the Ampex 721 sample evaluated to date cause most of the permanent 20 dB dropouts on 7 mil tracks with 33 kbpi packing densities. If the predominant defect type of each tape type can be eliminated, the dropout performance of 3M 5198 and Ampex 721 might approach the Fuji H621 results.

The deposit defects typical of 3M 5198 may be oxide binder chips produced during slitting or uncured components leached from the oxide binder system, deposited on the heads, and redeposited on otherwise insignificant projections from the oxide surface. They may be difficult to eliminate chemically since formulation changes are likely to affect desireable pro-

a.



b. ~12 mil

repetition
40" centers
few coarse
20db d.o.

Figure 2: (a) optical and (b) interference micrographs of defect Ampex 721-2-A. Magnifications are (a) 140 x and (b) 340 x.

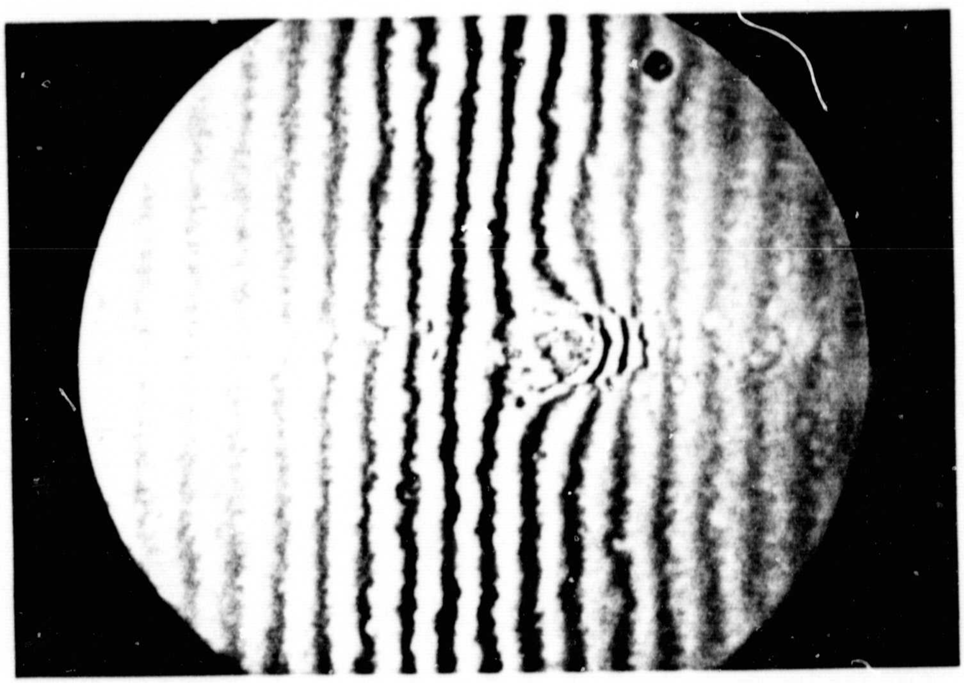


Figure 3: White light interference micrograph of defect Ampex 721-3-A magnified 340x.

perties of the 3M 5198 binder system. However, the deposit defects seem to be quite soft, so post production mechanical methods such as additional burnishing and cleaning can improve the 3M 5198 performance substantially. Exceptions to this improvement technique such as base film asperities and complete removal of oxide at calendaring marks have been observed.

Burnishing or other post production techniques are not likely to be effective for removing the base film asperities which seem to predominate on the Ampex 721 reel or the less common calendar marks. An awareness of the problem and an on-going evaluation of base film asperities by Ampex and their base film manufacturer (DuPont) was apparent during our recent visit to Redwood City. Our results define the magnitude of the problem and indicate the minimum significant size of defects relative to the packing densities under investigation.

As suggested in Section 6.2 of Progress Reports #12-15, only nominal effort was required to analyze the defects responsible for dropouts on the Ampex 721 reel. Several defect types can now be predicted from patterns of dropout repeatability, distribution, and signal envelope, supplemented by simple optical techniques. These results provide encouragement for the development and implementation of data analysis software for the IITRI dropout measurement system. It is apparent that the system will be capable of rapid and detailed dropout measurement and analysis which may be necessary to select the best media for the next generation of satellite recorders. Planned clean room installation of the system and ancillary tape handling equipment will permit conditioning and certification of tape prior to installation in a satellite recorder.

12.0 Summary

The broad scope of tape investigations conducted to date includes many theoretical aspects of tape performance and composition, which are difficult to interpret with respect to the needs of advanced HDDR systems and may have limited value in the selection and qualification of tape for STR applications. For those tests that provide more practical information, a well defined program of tape conditioning and environmental cycling should be implemented before selecting a tape type. In some cases, STR specifications should be defined more precisely before revising test methods to

better simulate application conditions. Due to the increased time and cost of tape conditioning during evaluation testing, the most critical STR performance parameters should be identified, and simple practical tests of these parameters should be conducted on a wider range of commercial products prior to selection of a tape type.

The following list suggests four categories of performance parameters which appear to be most critical to STR applications.

- o Tracking and guidance repeatability with environmental variations.
- o Low speed abrasion resistance and head-to-tape adhesion (friction properties) with environmental cycling over 50,000 passes.
- o Absolute dropout performance and performance changes after 100 passes, 1000 passes, and 10,000 passes (high speed abrasion resistance, cleanliness, and debris generation).
- o Thermal coefficient of coercivity or changes of electrical properties with environmental variations.

The list is based on previous test results and observations, discussions with manufacturers, previous recorder failures, and general considerations of longitudinal HDDR requirements. Implementation of a standardized procedure to investigate all of the properties in each category is recommended for future tape selection efforts. Additional tests such as lubricant type and content, lot-to-lot abrasivity variations, complete mangetic measurements, and chemical "fingerprinting" can be considered for tape qualification and requalification of later tape lots.

Past and current efforts are considered beneficial for a comprehensive understanding of the tape head interface of future STRs. Identification and analysis of problems that are not apparent as current densities may simulate tape manufacturers to investigate and improve their products, which will in turn provide consistent high quality tape for the next generation of NASA recorders and the HDDR industry in general.